
Industrial biotechnology and international trade: opportunities for developing countries

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Abstract: This paper explores the ability of developing countries to play a significant role in international trade in industrial biotechnology, a part of what is referred to here as the “new bioeconomy”. Sustaining the new bioeconomy requires adoption of global biotechnology governance regime that helps to bring a large number of developing countries into the global trading system. Failure to do so will create a “genetic divide” among countries and is likely to intensify public opposition to biotechnology. Such opposition is likely to be fuelled by presumptions about possible market dislocation and apparent features of technological disparities between nations. The elements of such a governance system include improvements in market access, development of technological capabilities, access to technology, national regulation of biotechnology, and the management of risks and benefits associated with its use.

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Introduction¹

The promise of biotechnology, a set of revolutionary techniques, has been the subject of public policy aspirations for the last two decades. In a call tempered by realism and caution, Agenda 21, the work programme adopted by the 1992 United Nations Conference on Environment and Development, asserted that biotechnology “promises to make a significant contribution in enabling the development of, for example, better health care, enhanced food security through sustainable agricultural practices, improved supplies of potable water, more efficient industrial development processes for transforming raw materials, support for sustainable methods of afforestation and reforestation, and detoxification of hazardous wastes.”

At face value, it appears that biotechnology has not lived up to its earlier promises, and this perception is reinforced by current debates over the safety of genetically modified (GM) foods. But a careful examination reveals biotechnology inroads into nearly all the major fields of human endeavor.² It is now a decade since world leaders signed onto Agenda 21. Since then, three major developments have occurred. First, the institutions of globalization that were being crafted at the time of the adoption of Agenda 21 are now in place, and their influence on the international trading system has become a subject of considerable debate. Second, biotechnology products have made their debut on the international market, and it is now possible to assess the performance of biotechnology in the global economy. Third, advances in biology (especially molecular biology) signal the prospect of a new generation of products and services that were not conceivable a decade ago.

This paper explores the ability of developing countries to play a significant role in what is clearly an emerging field, involving the wider application of modern biotechnologies in fields such as agriculture, medicine and industry. We refer to the confluence of modern biotechnologies and the market niches that they occupy as “the new bioeconomy”. The new bioeconomy will benefit from advances in other fields, especially informatics, and it will take root in countries and regions that take deliberate steps to create an enabling environment for its adoption. Sustaining a new bioeconomy requires the adoption of a global governance regime for biotechnology that helps to bring a large number of developing countries into the global trading system. Failure to do so will create a “genetic divide” among countries and is likely to intensify public opposition to biotechnology.³ Such opposition is likely to be fuelled by presumptions about possible market dislocation and apparent features of technological disparities between nations. The elements of such a governance system include improvements in market access, development of technological capabilities, access to

1. This paper builds on an earlier version prepared for the United Nations Conference on Trade and Development, Geneva. We are indebted to Derya Honça and Karen Fang (Center for International Development at Harvard University) and Alexey Vikhlyayev (United Nations Conference on Trade and Development, Geneva) for their support, additional information and comments on an earlier version of this paper.

2. Pew Initiative on Food and Biotechnology (2001) *Harvest on the Horizon: Future Uses of Agricultural Biotechnology*. Washington, DC: Pew Initiative on Food and Biotechnology.

3. Juma, C. (Forthcoming) “The new genetic divide: biotechnology in a globalizing world”, *International Journal of Biotechnology*.

technology, national regulation of biotechnology, and the management of risks and benefits associated with its use.

1 Biotechnology And International Trade: The New Bioeconomy

Advances in biotechnology-related fields such as genomics, genetic engineering, chemical engineering and cell technology are transforming the industrial process and management landscape. Microorganisms, enzymes or their products are replacing processes that heavily depended on chemicals, many of which are implicated in environmental damage. However, much discussion on biotechnology currently focuses on agricultural applications (and to some extent biomedical uses). The generic nature of biotechnology techniques make it possible to create a new bioeconomy with greater prospects for the commercialization of new biotechnology products and wider participation of the developing countries.⁴ This market inclusion model will differ from the current one in which technology is concentrated in a small number of countries and resistance to new products is widespread.⁵

Since its emergence, modern biotechnology has been associated with debates concerning benefits and risks. The ability to transform life itself to generate new products and services has been classified as a revolutionary technology with the same societal impacts as the information and communications revolution. With these high expectations have also come fears and concerns, which have captured public and policy attention worldwide. Concealed in the narrower debates about the impacts of biotechnology on human health and the environment are wider concerns about socio-economic considerations, which can be translated into market dislocations.

Indeed, early concerns about agricultural biotechnology focused on the possible impacts of genetic engineering or shifting the locus of production of raw materials and its potential to reduce the participation of developing countries in the global economy. Little attention was paid to the ability of the developing countries to use the same technologies to diversify their produce and become players in the new bioeconomy. The debate over the distribution of biotechnological capabilities is evident in the field of agriculture, where only a handful of countries are producing GM crops. This narrow distribution of capabilities is also a major source of international concern and a key factor in the acceptance of GM foods worldwide. Similar trends are likely to develop in the field of industrial biotechnology, unless the global governance of biotechnology is improved.

Although scientific advances in biotechnology appear to be concentrated in a smaller number of industrialized countries, there are various factors that would allow for the wider participation of developing countries in the new bioeconomy. The first factor is the growing

4. Models of biotechnology commercialization in small economies may be of relevance to most developing countries. See, for example, Marsh, D. (2000) *Fostering Innovation in a Small Open Economy: The Case of the New Zealand Biotechnology Sector*. Manchester, UK: Eighth International Joseph A. Schumpeter Society Conference, 28 June.

5. This view also takes into account key dimensions of international politics. See for, example, Pownall, I.E. (2000) "An international political economy view of the biotechnology industry", *Electronic Journal of Biotechnology*, Vol. 3, No. 2, pp. 1-20.

recognition that the current patterns of globalization are untenable, if they do not increasingly include developing country products. These countries depend on industries that are based on natural resources and therefore can benefit from the use of modern biotechnology. Second, many of the techniques used in biotechnology research are becoming readily available because of scientific familiarity, and are therefore relatively easy to acquire through sustained capacity development and enterprise development efforts. Thirdly, much of the initial R&D expenditures have already been borne by the industrialized countries and what is needed is effective international technology partnerships.

Taking advantage of these opportunities, however, will depend on the level of domestic technological capacity in the developing countries and the kind of global biotechnology governance system that emerges from the current policy debates. A global governance system that provides opportunities for market access will help to foster the commercialization of new technologies, especially those that threaten to alter the patterns and loci of production. In other words, resistance to new technologies is likely to be reduced by perceptions of access to the new technologies, as well as to their markets. This, indeed, has not been the case with agricultural biotechnology, which involves worldwide exports with the potential for product displacement, while leaving wide margins of uncertainty for technological followers.

Wider participation in the bioeconomy will also foster greater interest in the harmonization of regulatory practices among countries. This view is based on the claim that regulatory practices evolve from the practical management of technology. In other words, those who have the capacity to use modern biotechnology are also the ones who would have the means and interest to develop regulatory systems for that technology. An alternative scenario involves a small number of biotechnology exporters and a large number of countries that are likely to consider restrictive regulatory practices. This seems to be a possible scenario in the field of GM foods.

The fears of technological exclusion are real. The skills and detailed knowledge, from biology to engineering, needed for countries to become players in modern biotechnology are diverse and in-depth. In addition, equipment sophistication and finance must be globally competitive.⁶ Responses by developing countries to these requirements will vary considerably, depending on prior capabilities in relevant fields, existing strategies for enhancing national competitiveness in biotechnology and the degree of integration into global technological networks through joint ventures and strategic alliances.

The new bioeconomy is characterized by the emergence of institutional structures, as well as rules, that demand alternative technology cooperation approaches. First, the new bioeconomy has emerged concurrently with international trading rules that reinforce the market dominance of leaders in particular technological fields. These rules are reinforced by greater emphasis on instruments such as the Agreement on Trade-related Intellectual Property (TRIPs) under the World Trade Organization (WTO), which reduce the prospects for technological spillovers to developing countries. Second, globalization has intensified interactions among firms in the developed world and contributed to technological

6. Visalakshi, S. (2001) "Manpower requirement in biotechnology and strategies to achieve them-international and Indian experiences", *International Journal of Biotechnology*, Vol. 3, pp. 199-216.

convergence among firms in this region at the expense of linkages with firms in developing countries. Third, the new bioeconomy is driven largely by the private sector, with lesser participation of public sector enterprises. The growing role of the private sector in the industrialized countries demands a similar shift in the developing countries. This suggestion does not entail a reduction in the role of the public sector. However, it necessitates a review of the role of the public sector in a globalizing world. On the whole, a new technology governance regime is needed to foster technological cooperation, expand market opportunities for all major players, and expand the prospects for wider acceptance of biotechnology products.

2 Trends in industrial biotechnology

The last century saw the replacement of plant-derived products with petroleum derivatives. These remarkable transformations helped humanity to overcome some of the natural limitations of relying on natural processes. The change was largely a result of advances in chemistry and allied fields. This century promises to open new avenues for increasing the use of renewable resources in the global economy. These trends will open up new opportunities for the participation of developing countries in the new bioeconomy. But as in previous technological revolutions, the promise and reality are different. In the case of agricultural biotechnology, for example, only a handful of developing countries have so far managed to become players in the global economy. The rest have little hope of playing significant roles in the near future. As in other technological fields, participation in the new bioeconomy will be uneven and limited to those countries that make the necessary investments in technological development.

So far, much of the research on policy aspects of biotechnology has focused on agricultural and pharmaceutical biotechnology. The field of industrial biotechnology remains understudied. Industrial biotechnology covers two distinct areas. The first area is the use of renewable raw materials (biomass) to replace raw material derived from fossil fuels. The second is the use of biological systems such as cells or enzymes (used as reagents or catalysts) to replace conventional, non-biological methods.

Industrial application of biotechnology is emerging as a spin-off from developments in other fields such as the pharmaceutical sector. This emergence is largely because industrial biotechnology has not received the same level of public policy attention as has biotechnology in other sectors. There are other structural factors that influence the diffusion of industrial biotechnology. These include the dominance of physical and chemical technology as a source of concepts for the design of industrial plants limits the scope for introducing biological processes.

One of the main advantages of industrial biotechnology is the prospect for the controlled production of biological catalysts. These biocatalysts are more specific and selective than their non-biological counterparts. As a result, they offer greater potential for cleaner industrial production. In other words, biocatalysts generate fewer by-products and can start with relatively less purified feedstocks. And because they are self-propagating, they can be

used in applications such as waste treatment.⁷ But despite these advantages, biocatalysts are generally fragile (requiring large amounts of water) and have low volumetric productivity. Over the years, however, incremental technological innovations and new bioreactor designs have helped to improve the industrial performance of biocatalysts. With incremental improvements in biocatalysts and the emergence of new design concepts, biotechnology's capacity to diffuse in the industrial sector will be enhanced. This prospect is enhanced by the growth in the biological sciences, as well as complementary fields such as chemistry and informatics.

The use of biomass for energy and industrial uses has been on the agenda of many governments for nearly two decades. Much of the interest was triggered by the oil crises of the 1970s. Although interest in the field waned with the decline in energy prices, advances in the biological sciences have continued to enhance the prospects for technological improvement and wider application. In addition to energy, living plants can be used to produce chemicals such as citric acid, lysine and lactic acid. Genetic modification offers new possibilities for using plants as a source of raw materials for chemicals or even finished products. Monsanto, for example, has experimented with a genetically modified corn plant to produce a biodegradable plastic using a gene from a bacterium, *Ralstonia eutropha*. Similar experiments are underway in other chemical firms around the world. One of the most advanced efforts is an initiative by Cargill Dow Polymers (CCDP) to construct a plant to produce 140,000 tons a year of polylactide (a biodegradable plastic) using lactic acid fermented from corn.

As enzyme technology improves, attention is shifting to other areas of bioprocessing by tapping the potential in the world's splendor of microbial life. Much of this world remains underutilized largely because microorganisms have so far been poorly studied and documented. With the advent of DNA sequencing, microorganisms will become an important addition to industrial activities through scientists' discovery of new biocatalysts. The field of genomics is therefore likely to extend its influence from medicine and agriculture to industrial production. Methods such as forced evolution and rational design will increasingly be used to discover new enzymes for industrial use. In addition, methods such as gene shuffling are helping firms to optimize their bioprocessing activities.

It is expected that the genomes of major industrial microorganisms will be sequenced in the coming years, and this will add significantly to the genetic library of industrial biotechnology resource. Prospecting for biological organisms of industrial value will increase as bioprocessing gains acceptance. The network of agreements between bioprospecting firms such as Diversa and biotechnology-related firms such as Dow, Aventis, Glaxo, and Syngenta illustrates the growing increase in this field. These technological developments will result in new generations of chemicals and polymers that will compete directly with bulk petrochemical products.

7. OECD (1998) *Biotechnology for Clean Industrial Products and Processes: Towards Industrial Sustainability*. Paris: Organisation for Economic Cooperation and Development.

3 International market opportunities for developing countries

The evolution of market opportunities for industrial biotechnology is difficult to predict, partly because of the nascent nature of the industry, poor understanding of its structure, and a lack of concerted efforts to improve the policy environment for the diffusion of biotechnology products. What is likely to emerge, however, is a scenario dominated by niche markets in a wide range of sub-sectors. Furthermore, the blurring of boundaries between agriculture, health and industry makes it difficult to predict potential areas of market expansion. Even though the life science industries model is currently being questioned, the generic nature of the technology suggests that firms that have established a lead in pharmaceutical or agricultural biotechnology are likely to become equally important players in industrial biotechnology.

However, it is clear that industrial biotechnology has a wide range of starting points, which should lead to expansion. For example, enzymes are estimated to hold a world market value of \$1.6 billion, of which North America and Europe account for 35% and 31%, respectively. The share of the enzymes market in the textile and detergents sectors shrank, while that in animal feeds, specialty chemicals, and food applications increased at least five-fold, between 1992 and 1998.

Asia has the fastest growing market for feed additives, currently estimated to be over \$6 billion globally, followed by Latin America. Amino acids and vitamins account for about \$3 billion, digestive enhancers about \$1.3 billion and disease-preventing agents \$480 million. It is estimated that the amino acid and digestive enhancers market will continue to grow. The market for probiotics should continue to grow, following the introduction of legislation in Europe and other countries to prohibit the use of antibiotics in animal feed.

However, it is also important to note that a number of the current biotechnological products are more expensive than their traditional equivalents. Biopesticides are still lagging behind chemical pesticides due to target specificity (which is bad for business, but good for the environment), instability and batch (potency) variation. This makes the marketing and production of biopesticides difficult and their use by farmers, households and industry unattractive.

Bioplastics and biofuels have been more expensive than traditional plastics and petroleum-derived equivalents in developed countries. Although the gains to the environment, made by the use of these products, are hard to determine, bioplastics and biofuels remain worthwhile areas for development, especially since costs of production are dropping. Bioplastics are now commonly used in hospitals and in home products and disposable utensils. Further, the costs of petroleum products in developing and developed countries are different, which makes them attractive in the former. It is along these lines that genetic modification may increase the value, but reduce the cost of production of these products.

4 International policy options

The wider application of industrial biotechnology under current globalization trends will depend on the creation of an appropriate governance system for the new bioeconomy. For developing countries to participate effectively in the new bioeconomy, at least five key areas of the governance system will need to be adjusted: market access; international biotechnology alliances; intellectual property protection; regulation; and risk management. This section outlines some of the key recommendations that pertain to these areas of global governance.

4.1 Market access

Market access represents the greatest hurdle to international trade and consequently to technology access and acceptance. Although liberalization of markets has increased over the last 50 years following the numerous trade negotiations and integration of economies, many barriers to trade still exist, especially in labor-intensive sectors that are of interest to developing countries. The two major barriers are high tariffs and standards (sanitary and phytosanitary requirements). Agricultural products and industrial product exports to developed countries suffer most from tariff peaks.⁸ The EU and Japan have the highest number of tariff peak products for agricultural imports, while the US and Japan have the high number for industrial and electronic products imports. These products represent about 15% of the exports of least developed countries to the developed countries.

Other than tariff peaks, these products also suffer from tariff escalation. For example, exports of finished textile and clothing products to Canada attract about 16 times the tariff on raw materials for the same industry. Other products that suffer from incremental applied tariffs by stage production include leather, rubber, metal, wood and paper. These are all products where developing countries have particular interest. In manufacturing, developing countries products face tariffs of about 70% higher than those faced by developed countries.

Taken together, tariff peaks and escalations reduce the desire in developing countries to export finished products, thereby reducing diversification and skill accumulation. Because of high levels of subsidies to agriculture and export products in developed countries, most developing countries continue to be marginalized in international trade.⁹ In the absence of open markets, it is not surprising that developing countries do not invest heavily in export industries linked to the processing of raw materials.

Non-tariff restrictions such as quota allocation, voluntary export restraints and non-automatic licensing continue to affect exports from developing countries. Products affected by these measures include textile, sugar, rubber, minerals, machinery and precious stones in both developing and developed country markets. There are also fears that once these measures are

8. Tariff peaks are tariffs of 15% or higher, or three times the tariff in developed countries. Tariff escalation refers to increasing tariff with level of downstream processing.

9. The OECD support to agriculture is estimated at \$1 billion per day.

phased out, they are likely to be substituted by other measures such as anti-dumping or other technical barriers.

The requirement for exporters to meet product standards similar to those found in the importing countries is a critical element in international trade. However, if the exporter's home market standards are different from that of the export market, then extra cost has to be incurred to meet the demands. Many developing countries do not have sufficient facilities and personnel to conform to industrial market demands. Developing countries often import products that are banned in developed countries, while developed countries are more restrictive when it comes to imports from developing countries. The implications of these restrictive measures and other trade inhibitory mechanisms such as countervailing duties, safeguards, customs and administrative red tape on industrial biotechnology are potentially large. These measures will affect products such as polymers, fuels, paints, lubricants, fertilizers, plastics, and many others derived from biomass using industrial biotechnology.

Market access is an essential element of market liberalization, and special efforts are needed to create better trading opportunities for developing countries. In the absence of such improvements, trust in global markets will remain low, and the mistrust is likely to hinder the wider application of emerging technologies such as industrial processing and environmental management. Efforts to promote the wider use of industrial biotechnologies should involve measures aimed at reducing barriers to market entry for products originating from developing countries. This should be done in the context of measures aimed at fostering the emergence of the new bioeconomy.

4.2 Biotechnology alliances

One of the most significant developments in the structure of the global biotechnology industry is networks involving partnering activities.¹⁰ These networks are products of complex interlinkages between a wide range of enterprises, links which are designed to reduce the risks associated with the development of new products, as well as to facilitate information exchange. More specifically, these partnering arrangements help to provide sources of financing through licensing and upfront fees for R&D expenses, reimbursement of expenses for partnered products and services, royalties, profits and other "success fees" associated with the achievement of certain milestones. Such arrangements are particularly important in areas with limited access to other forms of financing, such as venture capital. Even where venture capital is available, these arrangements still serve an important risk-reducing function.

Partnering activities are naturally more concentrated in the industrialized countries, but these arrangements are being extended to developing countries, especially in agricultural biotechnology. Similar arrangements could be considered in industrial biotechnology. In addition to the risk-reducing benefits outlined above, partnering arrangements could also play a key role in the development of technological capabilities in the firms and institutions in

10. Mytelka, L. (1999) "New trends in biotechnology networking", *International Journal of Biotechnology*, Vol. 1, No. 1, pp. 30-41.

developing countries. Such capacity would be specialized and related to specific products and services. Furthermore, such partnering would also be useful in promoting the adoption of good management as industrial production standards in developing countries. It is therefore recommended that partnering models that are relevant to developing countries be identified and promoted as part of the expansion of the new bioeconomy.

4.3 Intellectual property systems

Emerging technologies are associated with strong regimes of intellectual property protection. Biotechnology is a particularly interesting area for two reasons. First, the patenting of living forms is a recent development that is specifically linked to policy measures to foster the establishment of the biotechnology industry. There are differences of opinion on the exact impact of patent protection on the evolution of the biotechnology industry. What is evident, though, is that complementary institutions such as venture capital would not have evolved to the extent that they did, without the existence of an intellectual property regime that provides comfort to investors and inventors alike.

In this regard, intellectual property protection has co-evolved with the biotechnology industry and is one of its key institutional attributes. There are, of course, many areas of industrial biotechnology in developing countries that have developed through the use of public domain technology and have therefore not been affected by increased intellectual protection barriers. This, however, is going to change as more countries are brought under the auspices of the TRIPs agreement, its successor arrangements and extra-judicial measures.

Trends in agricultural biotechnology suggest that the impact of intellectual property rights on the ability of developing countries to participate in the new bioeconomy varies considerably, depending on the nature of the research, level of technological development and enterprise size. Public sector research programs remain particularly vulnerable to changes in the intellectual property regime because of their traditional dependence on public domain technologies and lack of knowledge of intellectual property practices. Although this situation is starting to change, many developing countries are still far from mastering the details of inventive activity. It is paradoxical that for these countries to participate in the new bioeconomy, they will need to establish a certain level of familiarity and compliance with the emerging intellectual property rules. Ironically, however, these same rules might affect their ability to be players in the new bioeconomy.

Furthermore, most developing countries are still in the early stages of technological learning where access to patented technologies is essential for industrial development. The more advanced developing countries need to balance between their interest to have access to protected technologies now, while preserving the possibility that any of their future inventions will be protected. There are no general models that would enable countries to reflect these various balances in one strategy. However, there are specific areas that require policy attention. First, developing countries will need to ensure that they meet the minimum requirements for intellectual property protection and create suitable environments for inventive activity. In turn, developed countries should help increase the level of trust in the intellectual property system by seeking to balance strong intellectual property protection with

the need to broaden the base for technological partnerships with developing countries. Agricultural biotechnology firms are exploring ways of sharing their patented technologies with developing countries under special institutional arrangements, including flexible licensing arrangements. Similar measures may be needed in the field of industrial biotechnology.

4.4 Regulatory environments

There are two types of regulatory issue that deserve attention under the new bioeconomy. The first set is related to international trade in living modified organisms. The second set of regulatory issues involves measures that are designed to facilitate the adoption of industrial biotechnology. Industrial biotechnology regulations will be similar to those in agricultural or pharmaceutical industries, depending on the products, but have so far remained and will remain less controversial, for at least two reasons. Firstly, biotechnology products used in process management (e.g. enzymes in textile and leather processing) do not become part of the final product (cloth or shoes). Secondly, the enzymes do not have any ability to transfer the gene sequence from which they were produced to any other life forms. Industry is likely to recycle or bake the waste prior to discharge. Therefore, the main issue will be batch contamination and the quality of the discharge.

The potential environmental benefits of industrial biotechnology makes it attractive to those who are interested in promoting the transition towards sustainability. Incremental innovations as well as new design concepts will help to make these technologies competitive with their conventional counterparts. Such cost reduction is important, especially with biofuels and bioplastics that are not yet competitive with petroleum-derived equivalents. However, the use of transgenic organisms in food processing, biofertilizers and waste treatment will be more controversial than in bioplastics and biofuels. The kinds of concerns expressed in agricultural biotechnology may arise here and should be treated in the same way.

Evidence from the implementation of the Cartagena Protocol on Biosafety shows that building regulatory capacity for biotechnology is a complex process requiring considerable external assistance for most developing countries. Those countries that have capacity in biotechnology research are also in a better position to design and implement regulatory systems. This view suggests that the growth of regulatory capabilities in developing countries will remain uneven and will be sensitive to cost factors. There are numerous models for reducing regulatory costs, including regional centers, mutual recognition arrangements, as well as cost-sharing agreements between government and industry.

Another area that might require special attention is the use of environmental regulation to promote industrial sustainability. This regulatory field is relatively new, but it offers opportunities for expanding the adoption of environmentally sound biotechnologies. The main limiting factor is the low level of use of environmental regulations to promote the adoption of alternative technologies in developing countries. Also related to this are measures that seek to reduce the consumption of non-renewable raw materials and replace them with bioproducts. In order to promote the use of environmentally sound biotechnology, governments will need to specify areas where such technologies could result in specific

benefits. But such specification may need to be done under the framework of a broader policy initiative aimed at promoting industrial sustainability.

4.5 Economic risks and benefits

Much of the discussion about the risks of biotechnology deals with environmental and health issues. Equally important is the failure to manage these risks and benefits effectively is one of the main sources of resistance to the adoption of new technologies. There are institutions that deal with some aspects of risk and benefit management, such as anti-trust legislation. But these do not address the seemingly benign cases of product displacement. Generally, such adjustments are considered to be part of the evolution of markets. However, the pace and scale at which they happen could become a threat to the diffusion of the very technology that brings about new benefits. The use of pest-resistant crops, for example, could be seen as offering a wide range of economic and health benefits. But those who rely on the chemical industry for their livelihoods are likely to be direct and indirect sources of resistance to the new technology.

Early efforts to identify potential winners and losers is an important part of the technology development strategy. With this identification, it should be possible to manage both the risks and the benefits in a way that allows for relatively smooth technological transitions. Managing technological transition is not easy, partly because of the competitive nature of market behavior and the dominant view of losses as part of the institution of free markets. However, in the absence of measures that reduce radical market impacts, resistance to new technologies is likely to emerge and undermine the potential benefits to society. Intra-industry and inter-industry consultations are an essential element of such a technological transition strategy. Such consultation should lead to measures that promote market inclusion insofar as they do not unduly interfere with the functioning of the market. And in doing this, particular attention should be given to potential impacts on developing country enterprises.

Conclusion

This paper has outlined some of the salient features of the emergence of industrial biotechnology as a growing segment of the new bioeconomy. The wider adoption of these technologies will depend largely on the extent to which global economic governance provides adequate space for the emerging technologies. Of particular relevance is the ability of developing countries to participate in the new bioeconomy. The paper has stressed the importance of a more open market access system, flexible enforcement of intellectual property rights in industrialized countries and adherence to minimum protection standards in developing countries, wider technology partnerships through corporate alliances, enabling regulatory environments, especially those that promote the transition towards industrial sustainability, and more effective systems for managing the economic risks and benefits associated with the introduction of new technologies.